The Comparison Study of Distributed and Concentrated Winding Types in Interior Permanent Magnet Motor for Integrated Starter Generator

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Abstract— In this paper, distributed and concentrated winding type interior permanent magnet synchronous machines are designed and compared to use for an integrated starter generator. The characteristics are computed from equivalent circuit which consists of parameters obtained from finite element analysis. The comparison results are discussed, and the determined model is fabricated and tested.

I. Introduction

Integrating the alternator and starter motor could produce a lower system cost as well as provide extra functionality. For example, the higher power capability of the integrated starter/generator (ISG) allows the engine to be started rapidly and smoothly. This facility could allow the engine to be automatically stopped when it would otherwise be idling and then "instantly" restarted. This could provide significant fuel savings and reduce emissions in city traffic conditions [1].

Therefore, as one of proposes to make better automotive vehicle system, there is continual demand for better performance in ISG and many researchers are investigating it in several aspects. W.L.Soong et al study rotor design of Interior Permanent Magnet Synchronous Machines (IPMSM) [1]. Franco Leonardi and Michael Degner research ISG with a comparison of low and high voltage system [2]. Ion.Boldea presents several kinds of machines such as induction machine, switched reluctance machine, surface permanent magnet machines, etc [3]. They show comparison research, and propose a better solution for ISG. When considering all these opinions, IPMSM with multi layer rotor and higher voltage system has higher efficiency and larger constant power speed. However, practical manufacture condition cannot meet all these requirements.

In this paper, authors investigate IPMSM for ISG, but focus on only its different winding types; distributed and concentrated windings. The rotor has one layer, but V-shaped model, and 42V battery system is considered. The each winding type IPMSM is designed with optimal design process consisting of design of experiments (DOE) and response surface methodology (RSM) [4]. The performance of each optimized model is calculated by using equivalent circuits consisting of electric parameters such as resistance, inductance, electro-motive force (EMF), etc.[5]. The inductance and EMF, sensitively influenced by magnetic saturation, are obtained by finite element analysis (FEA). The calculation methods have been already studied even by these authors in [5]; however, the other calculation method for inductance is attempted in this paper. Fig. 1 shows the vector diagram and phase difference of fluxes to calculate inductance. Fig. 2 and Fig. 3 are optimal designed models and their inductance profiles, respectively. The detail explanation will be presented in extended paper about optimal design process, inductance calculation method, and characteristic analysis. The comparison results will be discussed as well for two models and between simulations and tests.

II. References

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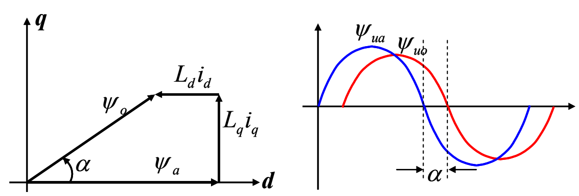
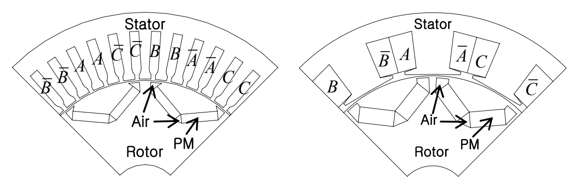
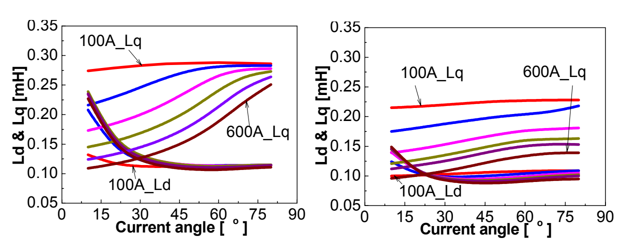


(a) Vector diagram (b) flux difference between load and no-load
Fig. 1. Vector diagram for inductance calculation



(a) Distributed winding type (b) Concentrated winding type
Fig. 2. Object configurations of IPMs



(a) Distributed winding type (b) Concentrated winding type
Fig. 3. Comparison of inductance profiles

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